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Signed, this 12th day of November 2007

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[Scope of Claim for Patent]

1. A reforming type fuel cell system provided with a reforming means for generating a reforming gas having hydrogen-richness by reforming reaction comprising:

a plurality of reactors constituting the reforming means;

a burner for generating a combustion gas warming up the reforming means, with a lean combustion; and

combustion gas supply passages for distributing the generated combustion gas by the burner to the plurality of the reactors.

2. A reforming type fuel cell system as defined in Claim 1, wherein:

the combustion gas is distributed so that the plurality of the reactors reach an operation temperature at the same time.

3. A reforming type fuel cell system as defined in Claim 2, wherein:

a generation amount of the reforming gas immediately after the warming up operation finish of the reforming means is set to warm up a volume-corresponding amount of the reactor covering at least the set reforming gas generation amount.

4. A reforming type fuel cell system as defined in any of Claims 1 to 3, wherein:

there is provided an air supply pipe for additionally flowing air into at least one of the combustion gas supply passages.

5. A reforming type fuel cell system as defined in Claim 4, wherein:

the air supply pipe is provided with a flow control valve for controlling a flow of the air.

6. A reforming type fuel cell system as defined in Claim 5, further comprising:

temperature estimating means for estimating a temperature of the reactor; and

in a case where the temperature estimated by the temperature estimating means is less than an operation temperature of the reactor, calculating means for calculating a heat amount required for the heating from the temperature, wherein:

the air is flown from the air supply pipe into the combustion supply passage based upon the calculation result of the calculating means.

7. A reforming type fuel cell system as defined in Claim 5, further comprising:

a combustion gas flow control valve disposed in at least one of the combustion gas supply passages; and

in a case where the temperature estimated by the temperature estimating means is less than an operation temperature of the reactor, calculating means for calculating a heat amount required for the heating from the temperature, wherein:

the combustion gas flow control valve is controlled based upon the calculation result of the calculating means to adjust a distribution ratio of the combustion gas to be distributed to the combustion gas supply passages.

8. A reforming type fuel cell system as defined in any of Claims 1 to 7, wherein:

the reforming means is formed by in series arranging a reforming reactor, a shift converter and a CO remover and the combustion gas is supplied to at least the reformer and the CO remover from the combustion gas supply passages.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[INDUSTRIAL FIELD]

The present invention relates to a reforming type fuel cell system and particularly to the warming up of a reformer.

[0002]

[CONVENTIONAL ART]

A warming up device at starting-up of the conventional reforming type fuel cell system is disclosed in JP05-303970A. This device warms up a reformer by a burner and an exhaust gas from the burner is supplied as a heating gas of a carbon monoxide removal device to warm up the reformer and the carbon monoxide removal device at the starting up of the fuel cell system.

[0003]

[PROBLEM TO BE SOLVED BY THE INVENTION]

However, the conventional device has the problem that a temperature of the heating gas supplied to the carbon monoxide removal device is low to lengthen the warming up time. This is because, since after heating the reformer, the heating gas is supplied to the carbon monoxide removal device for the warming up, the temperature of the heating gas supplied to the carbon monoxide removal device is low until the warming up of the reformer is finished. Therefore, since the warming up of the carbon monoxide removal device is made after the warming up of the reformer is finished, it requires a long warming up time.

[0004]

Therefore, an object of the present invention is to provide a fuel cell system which can quickly warm up a carbon monoxide removal device and the like.

[0005]

[MEANS FOR THE SOLUTION TO THE PROBLEM]

According to a first invention, a reforming type fuel cell system provided with a reforming means for generating a reforming gas having hydrogen-richness by reforming reaction comprises:

a plurality of reactors constituting the reforming means;

a burner for generating a combustion gas warming up the reforming means, with a lean combustion; and

combustion gas supply passages for distributing the generated combustion gas by the burner to the plurality of the reactors.

[0006]

In a second invention of the first invention,

the combustion gas is distributed so that the plurality of the reactors reach an operation temperature at the same time.

[0007]

In a third invention of the second invention,

a generation amount of the reforming gas immediately after the warming up operation finish of the reforming means is set to warm up a volume-corresponding amount of the reactor covering at least the set reforming gas generation amount.

[0008]

In a fourth invention of the third invention,

there is provided an air supply pipe for additionally flowing air into at least one of the combustion supply passages.

[0009]

In a fifth invention of the fourth invention,

the air supply pipe is provided with a flow control valve for controlling a flow of the air.

[0010]

In a sixth invention of the fifth invention,

there are provided temperature estimating means for estimating a temperature of the reactor; and

in a case where the temperature estimated by the temperature estimating means is less than an operation temperature of the reactor, calculating means for calculating a heat amount required for the heating from the temperature, wherein:

the air is flown from the air supply pipe into the combustion supply passage based upon the calculation result of the calculating means.

[0011]

In a seventh invention of the first or second invention,

there are provided a combustion gas flow control valve disposed in at least one of the combustion gas supply passages; and

in a case where the temperature estimated by the temperature estimating means is less than an operation temperature of the reactor, calculating means for calculating a heat amount required for the heating from the temperature, wherein:

the combustion gas flow control valve is controlled based upon the calculation result of the calculating means to adjust a distribution ratio of the combustion gas to be distributed to the combustion gas supply passages.

[0012]

In an eighth invention of any of the first to seventh invention,

the reforming means is formed by in series arranging a reformer, a shift converter and a CO remover and the combustion gas is supplied to at least the reformer and the CO remover from the combustion gas supply passages.

[0013]

[FUNCTION AND EFFECT]

According to the first invention, by providing the combustion gas supply passages for distributing the lean combustion gas generated by the burner at the system warming up, to the plurality of the reactors, the heating gas in a high temperature within a range of the heat proof temperature can heat the downstream-side reactor from the beginning and therefore, the warming up time of the downstream-side reactor can be shortened.

[0014]

According to the second invention, by distributing the combustion gas so that the plurality of the reactors reach the operation temperature at the same time, the reactor can be efficiently heated without heating each reactor to a high temperature more than necessary.

[0015]

According to the third invention, a generation amount of the reforming gas immediately after the warming up operation finish of the reforming means is set to warm up a volume-corresponding amount of the reactor covering at least the set reforming gas generation amount. Therefore, in a case where the set load is smaller than a predetermined value, the heat amount used for the warming up is smaller as compared to a case of warming up the entire reactor, making it possible to reduce fuel consumption.

[0016]

According to the fourth invention, there is provided the air supply pipe for flowing air into at least one of the combustion gas supply passages. Therefore, since the combustion gas temperature distributed to each reactor can be maintained to less than the heat proof temperature of each reactor, performance degradation of each reactor can be certainly prevented.

[0017]

According to the fifth invention, the air supply pipe is provided with the flow control valve for controlling a flow amount of the air. Therefore, an air amount

flowing into the combustion gas supply passage can be controlled and finally the combustion gas flow amount introduced into each reactor can be controlled, thereby appropriately distributing the combustion gas.

[0018]

According to the sixth invention, the air is flown into the combustion gas supply passages from the air supply pipe based upon the calculation result of the calculating means for calculating a heat amount required for the heating. This allows a temperature rise suitable for a temperature distribution generated between the reactors at the warming up start while avoiding excessive heating, based upon the cooling situation and the reactor temperature at the warming up.

[0019]

According to the seventh invention, by controlling the combustion gas flow control valve based upon the calculation result of the calculating means for calculating a heat amount required for the heating, a distribution ratio of the combustion gas distributed to the combustion gas supply passages is adjusted. In consequence, the heat amount used for the heating can be saved.

[0020]

According to the eighth invention, the reforming means is formed of in series arranging the reformer, the shift converter, the Oxidation reactor and the combustion gas supplied to at least the reformer and the Oxidation reactor. In consequence, since the combustion gas in a high temperature is supplied to the downstream-side Oxidation reactor from the combustion gas supply passages at the warming up, the warming up time can be shortened by a small amount of additional components.

[0021]

MODE OF CARRYING OUT THE INVENTION]

Referring to FIG. 1 of the drawings, a fuel cell power system for use in a vehicle comprises a reforming system for reforming hydrocarbon fuel such as gasoline

or ethanol to produce hydrogen rich gas, and a fuel cell stack 2 for performing power generation using hydrogen rich gas and oxygen.

The reforming system is constituted by a reforming reactor 3, a shift converter 4, and a preferential oxidation reactor (CO removal device) 5, which are connected in series. Hereinafter, these are referred to as reactor. An operation control of the fuel cell system is performed by a controller (not shown).

[0022]

Hydrocarbon fuel from a fuel tank 10 which is pressurized by a pump 11 is supplied to the reforming reactor 3 via a fuel passage 12. The supplied fuel is injected into the interior of the reforming reactor 3 by an injector 13. The reforming reactor 3 is also supplied with air from a compressor 1 via an air passage 61 comprising an air supply valve 21.

[0023]

The reforming reactor 3 reforms the mixture of air and hydrocarbon fuel using a known catalyst mediated reforming method such as steam reforming, partial oxidation, or autothermal reforming to thereby produce reformate gas having hydrogen as the main component thereof. This refomate gas contains carbon monoxide causing degradation of the fuel cell 2. Therefore, carbon monoxide is removed by the shift converter 4 and the carbon monoxide removal device 5 disposed at the downstream side of the reforming reactor 3

[0024]

The shift converter 4 reacts carbon monoxide (CO) contained in the reformate gas with water vapor using a catalyst to convert the carbon monoxide into carbon dioxide (CO), thereby reducing the CO concentration in the reformate gas. The CO removal device 5 reacts the carbon monoxide (CO) contained in the reformate gas with oxygen (02) in air using a catalyst to convert the carbon monoxide into carbon dioxide (COg), thereby reducing the CO concentration in the reformate gas. For this purpose, the CO removal device 5 is supplied with air from the compressor 1 via an air passage 62 which comprises an air supply valve 23.

[0025]

The fuel cell 2 generates power by using the hydrogen rich gas having a reduced carbon monoxide density and the air which flows from the compressor 1 through the air supply passage 63 and a flow amount of which is controlled.

[0026]

In such a fuel cell system, the following warming up operation is made for activating a catalyst filled in the reactors 3, 4, and 5 constituting the reformer at the activating.

[0027]

The fuel taken out from a fuel tank 10 by a pump 11 is supplied to the burner 6 through a fuel passage 14 and an injector 15. In the burner 6, combustion made with the supplied fuel and the air supplied from the compressor 1 through the air supply pipe 60. Here, a lean combustion gas (hereinafter, referred to as combustion gas) is generated by lean combustion having a low generation temperature and a small amount of carbon monoxide to be generated. The combustion gas is divided into combustion gas supply passages 71, 72 and 73 and supplied to the reforming reactor 3, the shift converter 4 and the oxidation reactor 5.

[0028]

After the combustion gas supplied to the reforming reactor 3 through the combustion gas supply passage 71 warms up the reforming reactor 3 ad the heating gas of the reforming reactor 3, the combustion gas is mixed with a combustion gas supplied through the combustion gas supply passage 72 in a gas mixer 31. The heating gas having a temperature lower than the combustion gas generated by this is supplied to the shift converter 4 to warm up the shift converter 4. After the warming up finish of the shift converter 4, the heating gas used for the warming up is mixed with the combustion gas supplied from the combustion gas supply passage 73 in a gas mixer 32. A further lower heating gas generated by this heats the oxidation reactor 5.

[0029]

The heated gas after the warming up of the oxidation device 5 is released outside of the fuel cell system. Since herein, the combustion gas having a low CO density generated by the lean combustion is used, the heated gas can be released outside of the fuel cell system through the fuel cell 2 after the warming up finish of the reformer.

[0030]

Here, because of the pressure loss generated in the reactors 3, 4 and 5 at the reforming operation after the warming up finish, a pressure in the upstream side in the reformer is higher than that in the downstream side thereof. In consequence, the reforming gas may flow out from the reactor in the upstream side to the reactor in the downstream side through the combustion gas supply passages 71 and 72. Therefore, the combustion gas supply passages 71 and 72 are provided with one-way valves 41 and 42 and thereby, it is prevented that unburned gases flow out in the downstream side.

[0031]

Next, by the warming up operation as described above, a heat amount required for each reactor 3, 4 and5 to be heated to a temperature showing a conversion rate.

[0032]

First, a target temperature necessary for each of the catalytic reactors 3-5 to achieve a conversion rate required for operating the fuel cell power system is set. The target temperature is a temperature at which the catalysts of the catalytic reactors 3-5 reach a predetermined state of activation. The target temperature differs among the catalytic reactors 3-5, but when the catalytic reactors 3-5 respectively reach their target temperature, the reforming system becomes able to supply the hydrogen rich gas that is necessary to begin operations in the fuel cell stack 2.

Here, if the catalyst temperature of the reforming reactor 3, the catalyst temperature of the shift converter 4, and the catalyst temperature of the CO removal device 5 are respectively set as Trp, Tsp, and Tcp when the fuel cell power system is operating normally, the relationship Trp > Tsp > Tcp is generally

established. The respective target temperatures of the catalytic reactors 3-5 are likewise set gradually higher toward the units on the upstream side.

[0033]

FIG. 3 shows a map used at the time of obtaining a target warming up temperature. When a volume flow amount of a reaction gas per unit catalyst volume is constant, a curve showing a conversion rate to a catalyst temperature is set as a SV curve. At this time, for obtaining an active state of a state of the reformer immediately after the warming up showing the conversion rate more than α, the warming up target temperature is set within a range of T1 to T2.

[0034]

When the warm up target temperature is thus set, a heat amount (required heat amount) required for achieving this warm up target temperature is obtained. Here, this is shown by a product of a difference between a warm up target temperature and a temperature of each reactor at the warm up start and a thermal capacity of each reactor.

[0035]

Required heat amount = thermal capacity of reactor× (warm up target temperature-warm up initial temperature) (1)

[0036]

For warming up each reactor 3, 4 and 5 in such a manner as to show the required conversion rate, it is required to supply the required heat amount by the heated gas. Therefore, a heat amount supplied to each reactor within a warming up time Ti is obtained.

[0037]

The heat amount absorbed by the catalytic reactors 3-5 during the period from the beginning of start up to the end of the set warm up time Ti is expressed in the following expression (2).

Ti Heat amount = f {specific heat of combustion gas flow rate temperature 0 difference between combustion gas at inlet and outlet of reactor (Æ0} dt (2) where, t = time elapsed from the beginning of warm up.

[0038]

The supply of the heat amount to each catalytic reactor 3-5 is provided in all cases by combustion gas supplied from the burner 6. If a set warm up time is assumed to be Ti, and if the target heat amount supply to each catalytic reactor 3-5 is completed upon the elapse of the set warm up time Ti from the beginning of warm up, then the catalytic reactors 3-5 achieve the conversion rate required to operate the fuel cell power system simultaneously.

[0039]

Here, a flow amount and a temperature or a composition of the heat gas is determined by the combustion gas generated in the burner 6. A flow amount and a temperature or a composition of the combustion gas is determined by a flow amount of air and fuel supplied to the burner 6. The air flow is controlled to a target value defined by a compressor 1 or by measuring it by an air flow meter (not shown). On the other hand, the fuel flow amount is controlled to a target value by a load of the injector 15 or by measuring it by a fuel flow meter (not shown). Here, the air amount and the fuel amount supplied to the burner 6 are constant.

[0040]

Next, for supplying the heat gas as described above, a distribution ratio of the combustion gas supplied to the each reactor is determined. Here, the distribution ratio shown in flow amount is constant regardless of the time and the warm up of the respective reactors 3, 4 and 5 is set to be substantially finished. In addition, a temperature of supplied combustion gas is set as T and time for warming up each reactor 3, 4 and 5 is set as warm up time Ti.

[0041]

If the temperature of the combustion gas produced in the burner 6 is assumed to be T, then combustion gas at temperature Tis directly supplied from the burner 6

via the combustion gas passage 71 to the reforming reactor 3 which is positioned furthest upstream of the catalytic reactors 3-5 as regards the flow of combustion gas.

[0042]

The amount of heat transfer to the reforming reactor 3 may be calculated in advance from the heating surface area and the thermal conductivity of the reforming reactor 3. If the amount of heat transfer to the reforming reactor 3 is known, the difference in temperature between the combustion gas at the inlet and outlet of the reforming reactor 3 may be expressed as a function fl (t of the time elapsed t from the beginning of warm up. Alternatively, by providing a temperature sensor 51 at the outlet of the reforming reactor 3 and monitoring the temperature Ta (0 detected by the temperature sensor 51 when combustion gas at temperature T is supplied to the reforming reactor 3, the temperature difference between the combustion gas at the inlet and the outlet of the reforming reactor 3 may be expressed as a function T-Ta (f) of the time elapsed t from the beginning of warm up. If the function fl (fJ or the function T -Ta (t) and the specific heat and flow rate Qa of the combustion gas, which are fixed values, are substituted into expression (2), the amount of heat absorbed by the reforming reactor 3 during the time period from the beginning of start up to the end of the set warm up time Ti may be calculated.

[0043]

The combustion gas supply flow rate Qa of the combustion gas passage 71 is determined such that the heat amount calculated in expression (2) satisfies the required heat amount calculated in expression (1). It can warm up the reforming reactor 3 for a warm up time Ti.

[0044]

The combustion gas supplied to the shift converter 4 is a mixed gas produced by mixing in the gas mixer 31 combustion gas which flows out from the reforming reactor 3 into the reformate gas passage 27 and combustion gas at temperature T supplied from the combustion gas passage 72.

[0045]

The temperature of the combustion gas which flows out from the reforming reactor 3 into the reformate gas passage 27 is equal to the temperature Ta (Q detected by the temperature sensor 51, and the flow rate thereof is equal to the combustion gas supply flow rate Qa of the combustion gas passage 71. If the flow rate of the combustion gas supplied from the combustion gas passage 72 is set as Qb, and Qa, Qb are both assumed to be constant values, then the temperature of the combustion gas that is supplied to the shift converter 4 is provided as a function of the time elapsed t from the beginning of warm up.

[0046]

The amount of heat transfer to the shift converter 4 may be calculated in advance from the heating surface area and thermal conductivity of the shift converter 4. Thus, from the amount of heat transfer to the shift converter 4 and by providing the temperature of the combustion gas supplied to the shift converter 4 as a function of the time elapsed t from the beginning of warm up, the temperature difference between the combustion gas at the inlet and the outlet of the shift converter 4 can be expressed as a function of the time elapsed t from the beginning of warm up.

However it is also possible to determine the temperature difference between the combustion gas at the inlet and outlet of the shift converter 4 experientially.

Specifically, a temperature sensor 52 is provided at the outlet of the shift converter 4, and with the shift converter 4 connected to the reforming reactor 3 and the combustion gas passage 72, the temperature Tb (o detected by the temperature sensor 52 is monitored while combustion gas is supplied to the reforming reactor 3 at the flow rate Qa, and combustion gas is supplied to the combustion gas passage 72 at the flow rate Qb.

In so doing, the temperature difference between the combustion gas at the inlet and the outlet of the shift converter 4 can be expressed as a function f2 (f) of the time elapsed t from the beginning of warm up. If the function f2 (0 and the specific heat and flow rate Qa+Qb of the combustion gas, which are constant values, are substituted into expression (2), the amount of heat absorbed by the shift converter 4 during the time period from the beginning of start up to the end of the set warm up time Ti may be calculated.

The combustion gas supply flow rate Qb of the combustion gas passage 72 is determined such that the heat amount calculated in expression (2) satisfies the required heat amount calculated in expression (1).

[0047]

The heat amount supplied to the CO removal device 5, which is positioned furthest downstream, is determined by calculating or experimenting the out let temperature of the shift converter 4. This determines the combustion gas flow amount Qc supplied to the CO removal device 5.

[0048]

Thus the heat amount required for warming up each reactor 3, 4 and 5 is calculated and the heat gas is supplied in such a manner that the heat amount supplied by the heat gas supplied to each reactor 3, 4 and 5 satisfies the required heat amount. Thereby, each reactor 3, 4 and 5 can be warmed up. At this point, by setting a supply ratio Qa, Qb and Qc of the combustion gas in such a manner that the warm up of each reactor 3, 4 and 5 are finished within a predetermined time Ti, the entire warm up time can be reduced. In addition, excessive warm up can be prevented, reducing fuel consumption.

[0049]

Further, the flow through cross sections of the combustion gas passages 71-73 are determined such that the combustion gas produced by the burner 6 is distributed among the combustion gas passages 71-73 at a ratio of Qa: Qb: Qc.

The cross sectional dimensions of the piping which constitutes the combustion gas passages 71-73 are determined in accordance with the determined flow through cross sections. Alternatively, the above distribution ratio may be realized by providing valves in the combustion gas passages 71-73 and setting the degree of opening of the valves.

[0050]

Changes in the catalyst temperature of the catalytic reactors 3-5 when a warm up device having specifications determined according to the aforementioned

procedures performs warm up of the catalytic reactors 3-5 are illustrated in FIG. 5. Here, the distribution ratio Qa: Qb : Qc is set as 4: 1: 1. Further, changes in the catalyst temperature of the catalytic reactors 3-5 in a similar reforming system when all of the combustion gas produced in the burner 6 is supplied to the reforming reactor 3 alone without distributing it to the shift converter 4 and CO removal device 5 as described above are illustrated in FIG. 4.

[0051]

Referring to FIG. 4, when all of the combustion gas is supplied to the reforming reactor 3 alone, the catalyst temperature of the reforming reactor 3 quickly reaches the target temperature, as shown by point A1. However, the combustion gas which is supplied to the shift converter 4 is reduced in temperature following transmission through the reforming reactor 3, and the combustion gas which is supplied to the CO removal device 5 has an even lower temperature following transmission through the shift converter 4, and as a result, as is shown by point B1 and point Cl, a great deal of time is required for the catalyst temperatures of these units 4,5 to reach their respective target temperatures. In order to prevent carbon monoxide poisoning of the fuel cell stack 2, carbon monoxide must be removed from the reformate gas produced by the shift converter 4 and CO removal device 5, but the reforming system cannot supply reformate gas to the fuel cell stack 2 when only the catalyst of the reforming reactor 3 has reached its target temperature. Hence the reforming system may only begin to supply reformate gas to the fuel cell stack 2 at point Cl in the drawing, and thus the time from the beginning of warm up to point C becomes the time required for warm up. Moreover, the reforming reactor 3 and the shift converter 4 are warmed unnecessarily during the interval from point Ai to point C 1 and the interval from point B, to point Cl respectively, with the result that a great deal of fuel is consumed up to the completion of warm up of the reforming system.

[0052]

Referring to FIG. 5, the warm up device according to this invention directly distributes the combustion gas from the burner 6 to the reforming reactor 3, shift converter 4, and CO removal device 5 through the combustion gas passages 71-73, and thus, in comparison with FIG. 4, although warm up completion in the reforming reactor 3 is delayed, warm up completion in the CO removal device 5

is greatly accelerated, as a result of which warm up in the reforming reactor 3, shift converter 4, and CO removal device 5 ends simultaneously. The warm up time can be reduced and also the fuel consumption amount can be reduced.

[0053]

Thus, by supplying the combustion gas to the reactor constituting the reformer, in particular the reactor in the downstream side, the reactor in the downstream side can be heated using the high-temperature gas from the beginning of the warm up operation. Further, by distributing the combustion gas in such a manner that each reactor can reach the target warm up temperature substantially at the same time, a further efficient heat can be made, reducing the warm up time.

[0054]

Next, a case where a load required after the warm up finish is not necessarily 100% will be explained. This is a case of, for example, using this fuel cell system at a vehicle or the like. A set load to be generated by a fuel cell at every running state is determined. Therefore, the reformer does not necessarily generate hydrogen corresponding to 100% load as a whole, but a temperature of only a catalyst corresponding to a volume amount by which a conversion performance can be obtained in accordance with the setting rises to an operation temperature.

[0055]

If the load during normal operations is assumed to be 100% and the load immediately after the start of power generation is assumed to be 50%, then as shown in FIG. 2 it is adequate for 50% of each catalyst in the catalytic reactors 3-5 to reach its target temperature. Since a catalytic reaction takes place to a certain extent even in the parts of the catalysts which have not reached the target temperature, the actual reformate gas supply capacity can sufficiently satisfy requirements as long as the proportion of catalyst warming is set equally to the required load proportion.

In order to realize this state of partial warm up, the required heat amount calculated in expression (1) is reduced in accordance with the load proportion and the set warm up time Ti is determined on the basis of the reduced required

heat amount. The burner 6 then ceases operations upon the elapse of the set warm up time Ti following the start of warm up.

[0056]

In this state of partial warm up, the temperature at the outlet of each catalytic reactor 3-5 is equal to the temperature prior to warm up, the shift converter 4 is warmed only by the heat of the combustion gas supplied from the combustion gas supply passage 72, and the CO removal device 5 is warmed only by the heat of the combustion gas supplied from the combustion gas supply passage 73.

[0057]

In this case, the amount of heat absorbed by each of the catalytic reactors 3-5 is expressed by the following expression (3).

Absorbed heat amount of reforming reactor 3: absorbed heat amount of shift converter 4: absorbed heat amount of CO removal device 5 = (heat amount required for warm up of entire reforming reactor 3-load proportion) : (heat amount required for warm up of entire shift converter 4-load proportion) : (heat amount required for warm up of entire CO removal device 5 toad proportion) (3)
In this case also, the combustion gas supply passages 71-73 in the warm up device directly distribute combustion gas from the burner 6 to the catalytic reactors 3-5, and hence it is possible to efficiently warm only the required part of each catalyst, thereby enabling a large reduction in warm up time and the amount of energy consumed for warm up.

[0058]

In this case, the smaller the required load immediately after the start of power generation in the fuel cell stack 2, the smaller the volume of the warm up subject in each catalytic reactor 3-5. It is therefore efficient to reduce the supply flow rate by heating the combustion gas to as high a temperature as possible without exceeding the heat resistant temperatures of the catalysts.

[0059]

Since the combustion gas is thus supplied to each reactor for distribution, the volume as a warm up object of each reactor 3, 4 and 5 can be set based upon the reforming gas generation amount required after the warm up finish and the combustion gas can be supplied in response to it, reducing the fuel consumption.

[0060]

If the heat resistant temperatures of the catalysts in the reforming reactor 3, the shift converter 4, and the CO removal device 5 are set as Tr, Ts, and Tc respectively, the relationship $Tr > Ts > Tc$ is generally established. If combustion gas is supplied at a temperature which exceeds the heat resistant temperature, the life of the catalyst is reduced due to the occurrence of sintering and the like, and hence combustion gas can only be supplied to the catalytic reactors 3-5 at a temperature which is equal to or lower than the heat resistant temperatures of the respective catalysts.

[0061]

In this warm up device, the combustion gas which is supplied to the shift converter 4 or CO removal device 5 is a mixture of high temperature combustion gas supplied from the combustion gas supply passage 72 or 73 and low temperature combustion gas which has been cooled in the reforming reactor 3 or the shift converter 4, which are positioned upstream, and hence if the temperature Tg of the combustion gas produced by the burner 6 is set in the range $Tr > Tg > Tc$, the temperature of the combustion gas which is supplied to any of the catalysts in the catalytic reactors 3-5 can be prevented from exceeding the heat resistant temperature thereof.

[0062]

By thus warming up a volume of a ratio in accordance with a load of the fuel cell system immediately after the warming up finish, the fuel used for the warming up can be saved, reducing an actual fuel consumption of the fuel cell system.

[0063]

The combustion gas supply passage 72 may be omitted from the warm up device for the following reason.

[0064]

The catalyst used in the CO removal device 5 is generally activated at low temperatures, but has poor durability in respect of high temperatures. It is therefore necessary to sufficiently mix the combustion gas which is supplied to the CO removal device 5 from the combustion gas supply passage 73 with the combustion gas which flows out from the shift converter 4 in order to reduce the temperature of the combustion gas which flows into the CO removal device 5 to or below the heat resistant temperature Tc of the catalyst. As a result, a large difference cannot be set between the temperature of the combustion gas which flows into the CO removal device 5 and the initial temperature, and thus warming of the catalyst in the CO removal device 5 tends to take time.

The temperature of the combustion gas which flows out from the shift converter 4 into the reformate gas passage 28 increases in accordance with the amount of time elapsed from the beginning of warm up. On the other hand, the temperature of the combustion gas which is supplied to the reformate gas passage 28 from the combustion gas passage 72 is constant. Hence the temperature of the combustion gas which flows into the CO removal device 5 rises in accordance with the amount of time elapsed t from the beginning of warm up. If the temperature of the combustion gas which flows into the CO removal device 5 is to be suppressed to or below the heat resistant temperature Te at the point of warm up completion on the basis of this characteristic, the temperature of the combustion gas which flows into the CO removal device 5 at the beginning of warm up must be greatly below the heat resistant temperature Tc. However such a temperature characteristic in the combustion gas which flows into the CO removal device 5 delays heat absorption in the CO removal device 5, thereby prolonging warming of the catalyst in the CO removal device 5.

By omitting the combustion gas supply passage 72, the flow rate of the combustion gas which flows out from the shift converter 4 is decreased and the flow rate of the combustion gas in the combustion gas supply passage 73 is increased. As a result, the difference between the temperature of the combustion gas which flows into the CO removal device 5 at the beginning of

warm up and the temperature of the combustion gas which flows into the CO removal device 5 at the point of warm up completion is reduced. Hence by omitting the combustion gas supply passage 72, the amount of time required to warm up the CO removal device 5 can be reduced while the temperature of the combustion gas which flows into the CO removal device 5 is suppressed to or below the heat resistant temperature Tc.

[0065]

A second embodiment of this invention will now be described.

[0066]

A warm up device according to this embodiment is further provided with air supply passages 64, 65 to which air is supplied by a compressor 1 in the midway of the combustion gas supply passages 72 and 73 to the shift converter 4 and the CO removal device 5, and air supply valves 22,23 in addition to the constitution of the warm up device according to the first embodiment in FIG. 1.

[0067]

Moreover, in the first embodiment the temperature sensors 51-53 were described as experiment equipment for obtaining design data, but in this embodiment the temperature sensors 51-53 are provided as constitutional elements of the warm up device. The warm up device of this embodiment is also provided with a controller 82 for controlling the opening of the air supply valves 22 and 23 during start up of the fuel cell power system.

Meanwhile, the gas mixers 31 and 32 provided in the first embodiment have been omitted from this embodiment.

The air supply passage 64 supplies the combustion gas supply passage 72 with air from the compressor 1 through the air supply valve 22. The air supply passage 65 supplies the combustion gas supply passage 73 with air from the compressor 1 through the air supply valve 23. The temperatures detected by the temperature sensors 51-53 are respectively input into the controller 82 as signals.

[0068]

In the first embodiment, the flow through cross sections of the combustion gas supply passages 71-73 were set with the set initial temperature as a fixed value, but in actuality the temperature at the starting point of warm up is not constant. The temperatures of the catalytic reactors 3-5 at the starting point of warm up may also differ according to individual cooling conditions such as the disposal around the reactors of apparatus with a large thermal capacity, a large cooling air flow rate, or cooling by a liquid with a large thermal capacity.

Such differences in initial temperature lead to differences in the amount of heat required for warm up. In this embodiment, the air supply routine executed by the controller 82 serves to compensate for such differences.

[0069]

In executing this routine, when the heat amount required for warming up the shift converter 4 which is calculated from the temperature detected by the temperature sensor 52 is smaller than the set warm up heat amount, for example, the air supply valve 22 is opened to supply air from the air supply passage 64 to the combustion gas supply passage 72. By supplying air to the combustion gas supply passage 72, pressure loss in the combustion gas flowing through the combustion gas supply passage 72 increases and the flow rate of the combustion gas decreases.

As a result, the temperature of the gas which is supplied to the shift converter 4 falls and the amount of heat absorbed by the shift converter 4 decreases. On the other hand, a reduction in the combustion gas supply flow rate of the combustion gas supply passage 72 leads to an increase in the combustion gas supply flow rate of the combustion gas supply passages 71 and 73, thereby increasing the amount of heat supplied to the reforming reactor 3 and the CO removal device 5. As a result, the warm up time of the reforming reactor 3 and the CO removal device 5 can be shortened.

[0070]

Further, when the amount of heat required for warming up the CO removal device 5, calculated from the temperature detected by the temperature sensor

53, is smaller than the set warm up heat amount, the air supply valve 23 is opened to supply air from the air supply passage 65 to the combustion gas supply passage 73. By supplying air to the combustion gas supply passage 73, pressure loss accompanying the flow of combustion gas through the combustion gas supply passage 73 increases and the flow rate of the combustion gas decreases. As a result, the amount of heat supplied to the CO removal device 5 decreases and the amount of heat supplied to the reforming reactor 3 and the shift converter 4 increases by a commensurate amount.

[0071]

In order to describe such phenomena, pressure loss in the combustion gas supply passages 71-73 must be considered. Pressure loss in each of the combustion gas supply passages 71-73 has a relationship as shown in the following expression (4).

[0072]

Pressure loss in combustion gas supply passage 71 = pressure loss in combustion gas supply passage 72-pressure loss in reforming reactor 3 = pressure loss in combustion gas supply passage 73- (pressure loss in reforming reactor 3 + pressure loss in shift converter 4) (4)

[0073]

If the combustion gas supply passages 71-73 are regarded as pipe bodies, each pressure loss in expression (4) can be calculated according to the following expression (5).

[0074]

Pressure loss = pressure loss coefficient- (pipe extension/pipe diameter). gas density {(gas flow velocity) 2/2} (5)

[0075]

A logical value or an experiential value may be applied to the pressure loss coefficient of the catalytic reactors 3-5 and the combustion gas supply passages

71-73. If the opening of the air supply valves 21 to 23 is further controlled such that the pressure loss in each of the catalytic reactors 3-5 and the combustion gas supply passages 71-73 determined according to expression (5) satisfy the relationship in expression (4), the timing of warm up completion in the catalytic reactors 3-5 can be aligned at all times regardless of the initial temperature of the catalysts in the catalytic reactors 3-5.

[0076]

A case in which the CO removal device 5 requires no warming whatsoever, or in other words when the catalyst of the CO removal device 5 has already reached operating temperature, can be considered as an example. In this case, in order that the temperature of the gas which is supplied to the reformate gas passage 28 from the combustion gas supply passage 73 becomes equal to the operating temperature of the CO removal device 5, the controller 82 sets the supply flow rate of the air which is supplied to the reformate gas passage 28 from the air supply passage 65 and controls the air supply valve 23 to a corresponding degree of opening. In consequence, the flow amount ratio of the combustion gas flowing in the upstream-side reforming reactor 3 and the shift converter 4 can be maximized while maintaining the CO removal device 5 at an operation temperature, thereby effectively using the heat amount of the combustion gas.

[0077]

As a result of supplying air to the combustion gas supply passage 73, pressure loss in the combustion gas in the combustion gas supply passage 73 increases, whereby the flow rate of combustion gas supplied to the reforming reactor 3 and shift converter 4 rises. Further, since the temperature of the gas flowing into the CO removal device 5 falls to the vicinity of the operating temperature, the catalyst temperature of the CO removal device 5 is maintained at the operating temperature.

Further, when the temperature of the gas flowing into the shift converter 4 threatens to exceed the heat resistant temperature Ts of the catalyst in the shift converter 4, the controller 82 manipulates the air supply valve 22 to increase the flow rate of the air which is supplied to the combustion gas supply passage 72 from the air supply passage 64, whereby the temperature of the gas flowing into

the shift converter 4 can be reduced. Similarly, when the temperature of the gas flowing into the CO removal device 5 threatens to exceed the heat resistant temperature Tc of the catalyst in the CO removal device 5, the controller 82 manipulates the air supply valve 23 to increase the flow rate of the air which is supplied to the combustion gas supply passage 73 from the air supply passage 65, whereby the temperature of the gas flowing into the CO removal device 5 can be reduced. The temperature Tg of the combustion gas produced by the burner 6 can be set accordingly to a value close to the heat resistant temperature Tr of the reforming reactor 3.

[0078]

When the amount of heat supplied to the catalytic reactors 3-5 is controlled by means of the air supply amount, the temperature of the gas which flows into the shift converter 4 can be suppressed to or below the heat resistant temperature Ts even when gas mixing is not performed sufficiently at the point of convergence between the combustion gas supply passage 72 and the reformate gas passage 27. Similarly, the temperature of the gas which flows into the CO removal device 5 can be suppressed to or below the heat resistant temperature Tc even when gas mixing is not performed sufficiently at the point of convergence between the combustion gas supply passage 73 and the reformate gas passage 28.

[0079]

Hence the omission of the gas mixers 31 and 32 in this embodiment is made and the pressure loss by the mixer can be reduced. Therefore, the pressure for supplying air to the reformer at the activation can be reduced. In consequence, a consumption power at the activation of an air supply device 1 can be reduced..

[0080]

Next, referring to FIG. 7, a third embodiment of this invention will be described.

[0081]

Referring to FIG. 7, a warm up device according to this embodiment is provided with a flow control valve 80 in the merging portion between the combustion gas

supply passage 73 and the air passage 65 to the CO removal device 5 in place of the air supply valves 22 and 23 of the second embodiment.

[0082]

In the second embodiment, the flow rate of the combustion gas which is supplied to the catalytic reactors 3-5 was altered by means of air supply from the air supply valves 22 and 23, but in this embodiment the flow rate of the combustion gas which is supplied to the CO removal device 5 is altered by manipulating the flow control valve 80.

[0083]

Thus the combustion gas flow amount control valve 80 is disposed downstream of the mixing portion between the combustion gas and the air. Thereby, the combustion gas flow amount control valve 80 can be made of a material having a low heat resistance. In addition, the combustion gas flow amount control valve 80 is disposed only in the CO removal device 5 having a low operation temperature and a low heat gas temperature at the warm up and therefore, the flow amount of the combustion gas can be adjusted without using an expensive valve with a high heat resistance.

[0084]

In this embodiment, set warm up heat amounts HaO, HbO, HcO for each of the catalytic reactors 3-5 are calculated in advance using expression (1) with the initial temperatures of the catalytic reactors 3-5 as fixed values, and the flow through cross sections of the combustion gas passages 71-73 are determined on the basis of the result thereof and the flow rate of the air supplied from the air supply passages 64 and 65. Calculating means calculates a heat amount required for the heating of the CO removal device 5 and the reactors 3 and 4 other than it. A degree of opening of the flow control valve 80 is controlled to correspond to a ratio of a heat amount required for the heating of the CO removal device 5 and the reactors 3 and 4 other than it so that the combustion gas is distributed in the CO removal device 5 and the reactors 3 and 4 other than it.

[0085]

At the activation from the cold state, the opening of the combustion gas flow control valve 80 is increased to set in such a manner that a distribution amount of the combustion amount to the oxidation device 5 is a heat amount ratio required at warm up from the clod state.

[0086]

Meanwhile, when the entire reformer is not completely cooled, the heat amount is not required so much.for the reheating, as the reactor has a larger thermal capacity and a lower reaction temperature. The reactor having a high operation temperature has a large release heat amount from the reactor at the system stop since a temperature difference from the atmosphere is large and for a little while after the operation stop, a difference between the operation temperature and the reaction temperature thereof becomes large as compared to the reactor in the downstream side.

[0087]

In this case, in the reactor in which an operation temperature in the downstream side like the oxidation device 5 is low, the heat amount supplied at the reactivation, is permitted to be small and in the reactor in which an operation temperature in the upstream side is high, a large heat amount is required. Therefore, at the reactivation when the entire reformer is not completely cooled, the combustion gas flow amount to the oxidation device as compared to the activation from a normal cold state is made small and the combustion gas amount to the reforming reactor 3 and the shift converter 4 increases. Thereby, the time until heat termination of the entire reformer is shortened.

[0088]

In a case of determining these distribution ratios, by applying a method of calculating the distribution ratio in the first embodiment, the distribution ratio at this time may be calculated or a correlation table between a reactor temperature distribution and a required heat amount is in advance obtained experimentally for use.

[0089]

An air supply valve 22 similar to that of the second embodiment may be provided in the air supply passage 64.

[0090]

Although the invention has been described above by reference to certain embodiments of the invention, the invention is not limited to the embodiments described above. Modifications and variations of the embodiments described above will occur to those skilled in the art, in light of the above teachings.

[BRIEF DESCRIPTION OF THE DRAWINGS]

FIG. 1 is a schematic diagram of a reforming fuel cell power system in a first embodiment.

FIG. 2 is an explanatory diagram illustrating a volume as a warm up object in a reactor when an output smaller than a rated operation in the first embodiment.

FIG. 3 is a diagram illustrating a warm up temperature of the reactor to a required conversion rate.

FIG. 4 is a diagram illustrating the relationship between the warm up time and the temperature of each reactor when combustion gas is not supplied to each reactor in the reforming system.

FIG. 5 is a diagram illustrating the relationship between the warm up time and temperature of each reactor when combustion gas is supplied to each reactor in the reforming system..

FIG. 6 is a schematic diagram of a reforming fuel cell power system in a second embodiment of this invention.

FIG. 7 is a schematic diagram of a reforming fuel cell power system in a third embodiment of this invention.

[DESCRIPTION OF THE CODES]

2: FUEL CELL

3: REFORMING REACTOR

4: SHIFT CONVERTER

5: CO REMOVAL DEVICE

6: COMBUSTION DEVICE

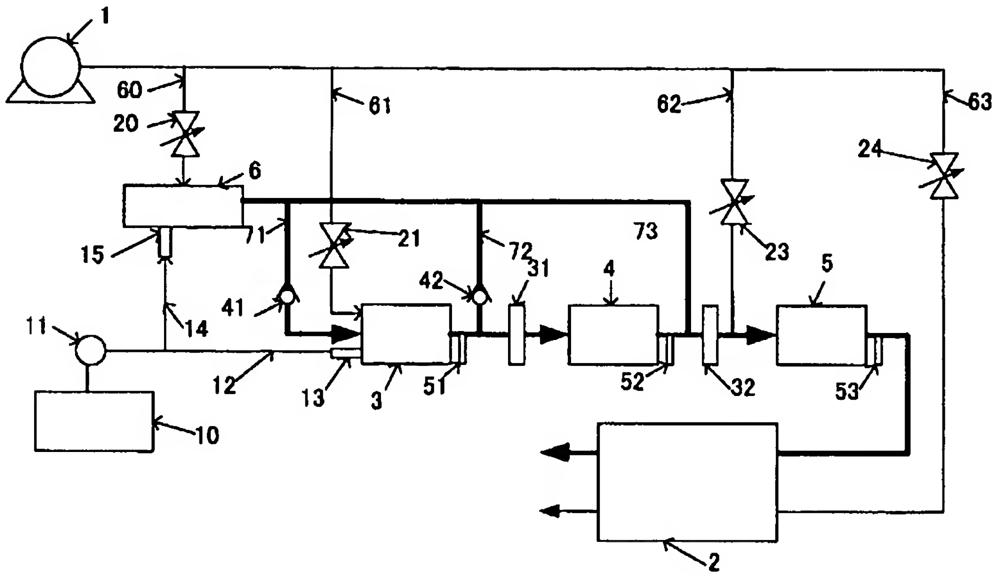
61 to 65: AIR PASSAGE

71 to 73: COMBUSTION GAS PASSAGES

80: COMBUSTION GAS CONTROL VALVE

[DOCUMENT TITLE] DRAWING

[FIG. 1]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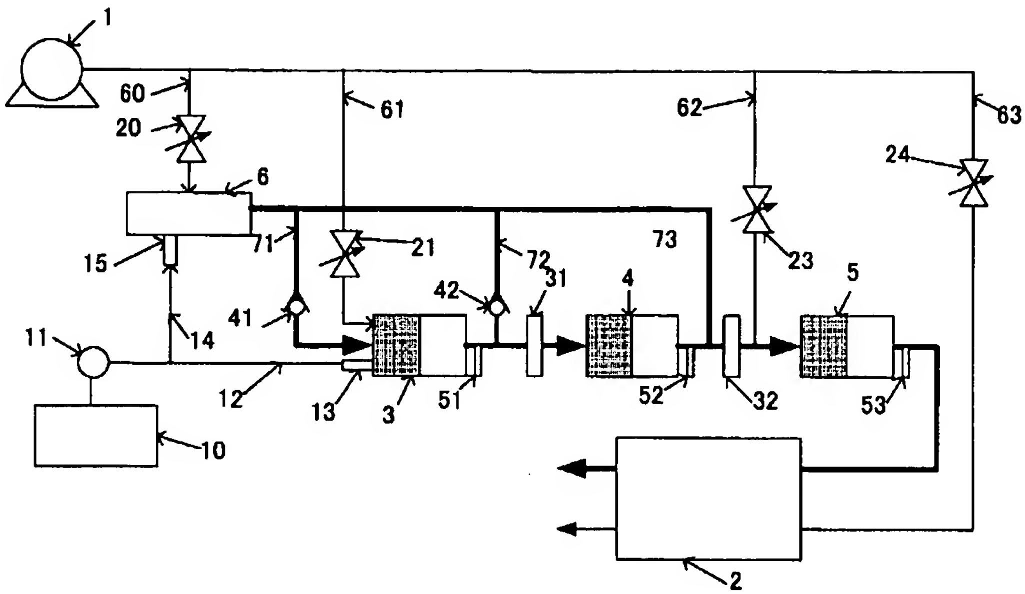
[FIG. 2]



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[FIG. 3]

CONVRESION RATIO

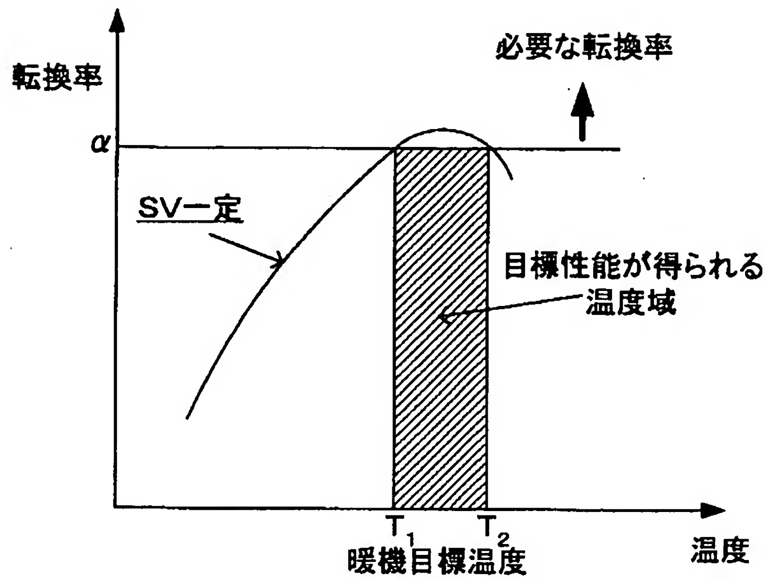
REQUIRED CONVERSION RATIO

SV CONSTANT

TEMPERATURE RANGE IN WHICH TARGET PERFORMANCE IS OBTAINED

WARM UP TARGET TEMPERATURE

TEMPERATURE



転換率
必要な転換率
α
SV一定
目標性能が得られる
温度域
T1
T2
暖機目標温度
温度

[FIG. 4]

REACTOR TEMPERATURE

CASE WHERE COMBUSTION GAS IS NOT DISTRIBUTED

REFORMING REACTOR TEMPERATURE

POINT A

WARM UP TARGET TEMPERATURE OF REFORMING REACTOR

WARM UP TARGET TEMPERATURE OF SHIFT CONVERTER

WARM UP TARGET TEMPERATURE OF CO REMOVAL DEVICE

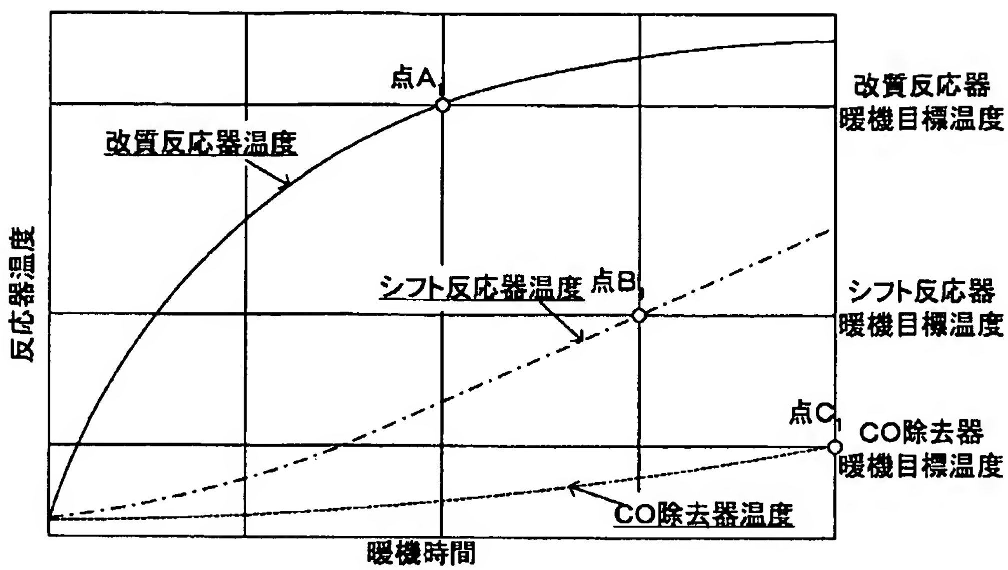
SHIFT CONVERTER TEMPERATURE

POINT B

CO REMOVAL DEVICE TEMPERATURE

WARM UP TIME

燃焼ガスを分配しない場合



[FIG. 5]

REACTOR TEMPERATURE

CASE WHERE COMBUSTION GAS IS NOT DISTRIBUTED

(DISTRIBUTION RATIO: 4: 1: 1)

REFORMING REACTOR TEMPERATURE

POINT A

WARM UP TARGET TEMPERATURE OF REFORMING REACTOR

WARM UP TARGET TEMPERATURE OF SHIFT CONVERTER

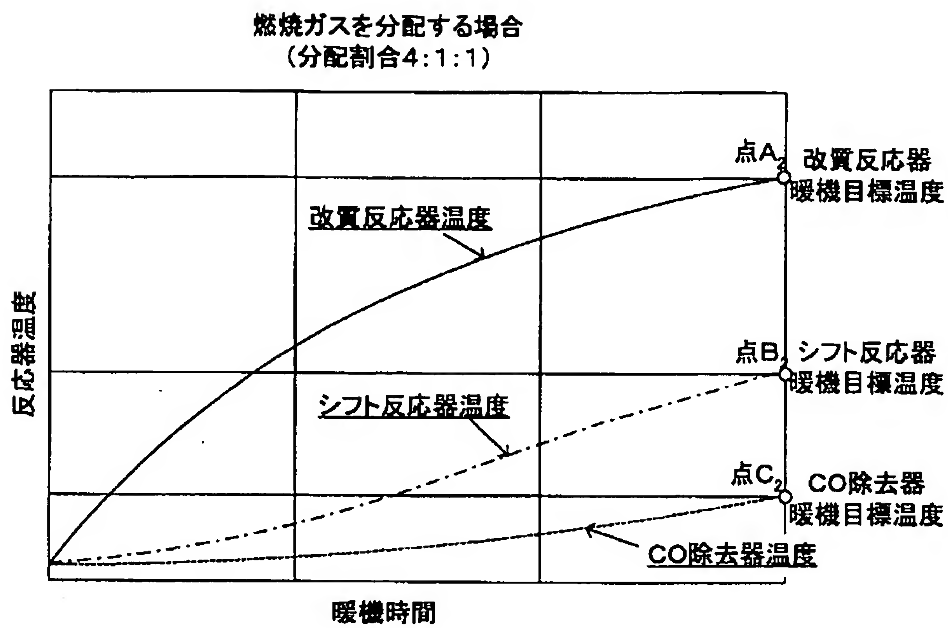
WARM UP TARGET TEMPERATURE OF CO REMOVAL DEVICE

SHIFT CONVERTER TEMPERATURE

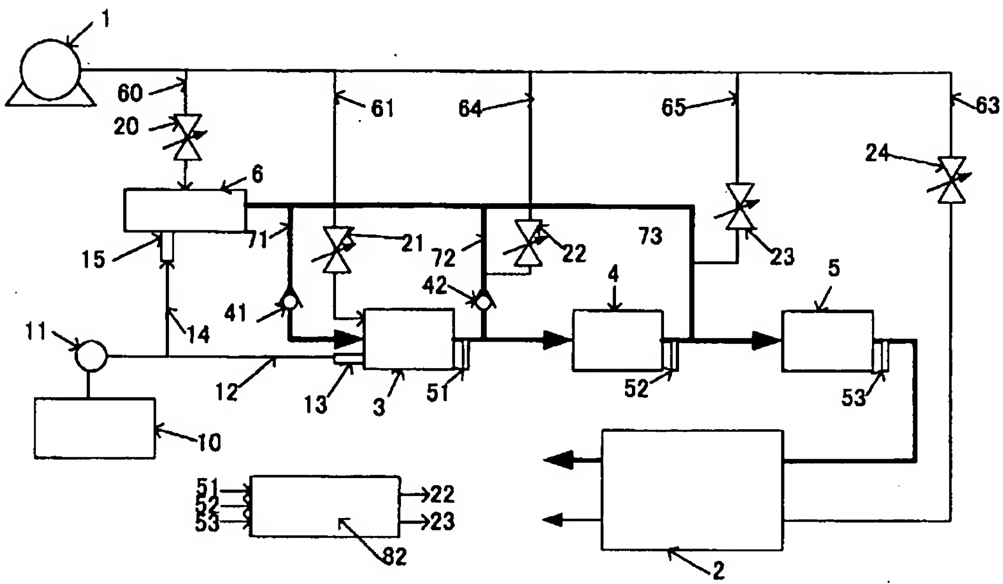
POINT B

CO REMOVAL DEVICE TEMPERATURE

WARM UP TIME


燃焼ガスを分配する場合
（分配割合4：1：1）
点A2
改質反応器
暖機目標温度
改質反応器温度
点B2
シフト反応器
暖機目標温度
シフト反応器温度
点C2
CO除去器
暖機目標温度
CO除去器温度
反応器温度
暖機時間

[FIG. 6]



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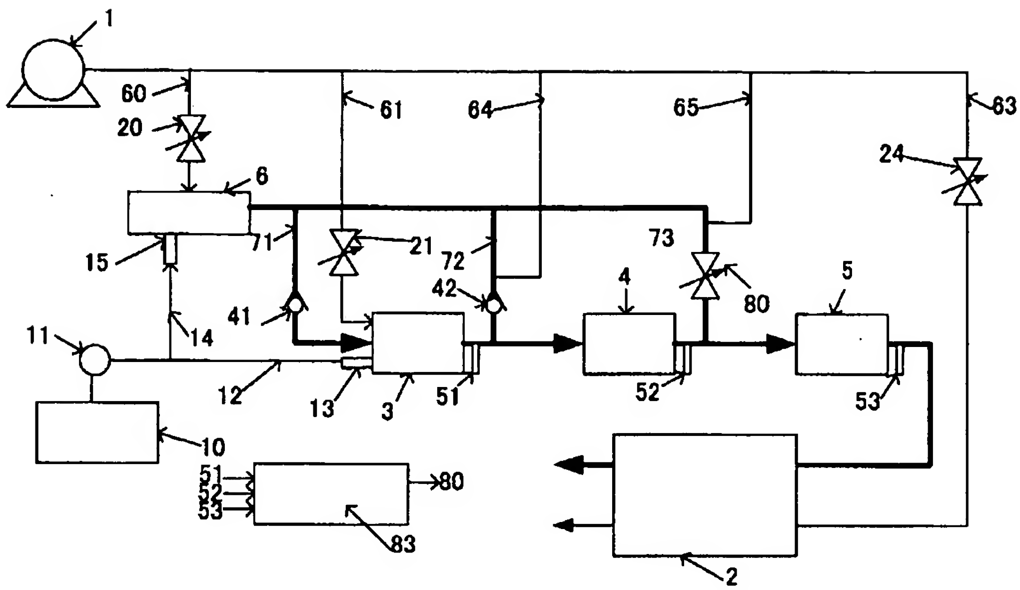
[FIG. 7]



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[ABSTRACT] ABSTRACT

[ABSTRACT]

To provide a fuel cell system which can warm up it for a short time.
[PROBLEM]
In a fuel cell system provided with a reforming means generating a hydrogen-rich reforming gas by reforming reaction, the reforming means is constructed of a plurality of reactors 3, 4 and 5 and there are provided a burner 6 for generating a combustion gas warming up the reforming means at system warming up and combustion gas supply passages 71, 72 and 73 for distributing the combustion gas generated by the burner 6 to the reactors 3, 4 and 5. In addition, a distribution ratio of the combustion gas is set so that the warm up finish time of each reactor 3, 4 and 5 is substantially the same.

[SELECTIVE DRAWING] Fig. 1